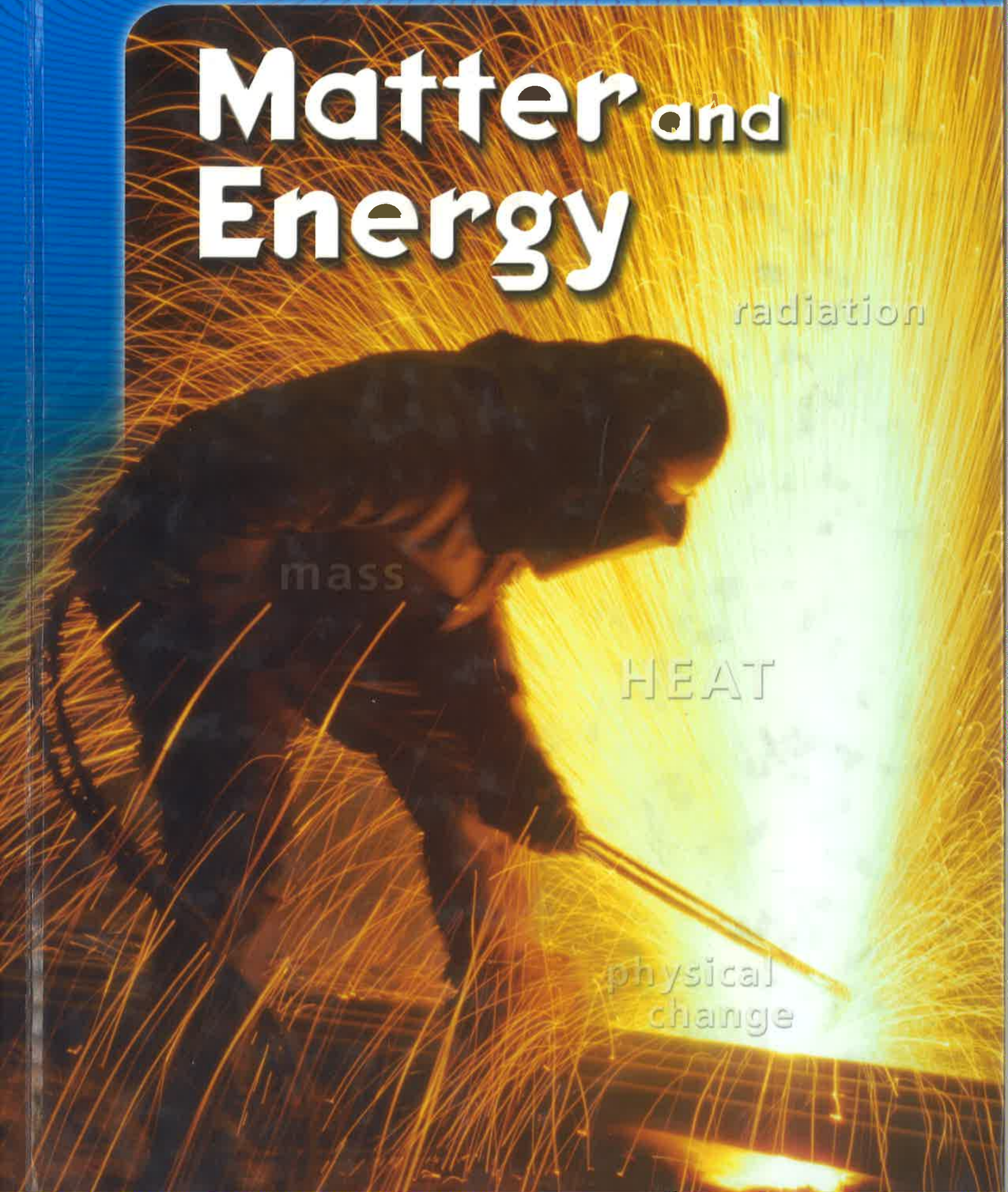
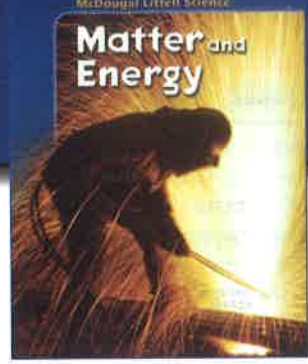
McDougal Littell Science

Matter and Energy





eEdition

Matter and Energy

Unit Features

SCIENTIFIC AMERICAN

1 Introduction to Matter 6

the BIG idea
Everything that has mass and takes up space is matter.

2 Properties of Matter 38

the BIG idea
Matter has properties that can be changed by physical and chemical processes.

What properties could help you identify this sculpture as sugar? page 38

What different forms of energy are shown in this photograph? page 68

3 Energy 68

the BIG idea
Energy has different forms, but it is always conserved.

4 Temperature and Heat 100

the BIG idea
Heat is a flow of energy due to temperature differences.

Handbooks and Resources R1

Introducing Physical Science

Scientists are curious. Since ancient times, they have been asking and answering questions about the world around them. Scientists are also very suspicious of the answers they get. They carefully collect evidence and test their answers many times before accepting an idea as correct.

In this book you will see how scientific knowledge keeps growing and changing as scientists ask new questions and rethink what was known before. The following sections will help get you started.

UNIFYING PRINCIPLES of Physical Science

What Is Physical Science?

In the simplest terms, physical science is the study of what things are made of and how they change. It combines the studies of both physics and chemistry. Physics is the science of matter, energy, and forces. It includes the study of topics such as motion, light, and electricity and magnetism. Chemistry is the study of the structure and properties of matter, and it especially focuses on how substances change into different substances.

The text and pictures in this book will help you learn key concepts and important facts about physical science. A variety of activities will help you investigate these concepts. As you learn, it helps to have a big picture of physical science as a framework for this new information. The four unifying principles listed below will give you this big picture. Read the next few pages to get an overview of each of these principles and a sense of why they are so important.

- **Matter is made of particles too small to see.**
- **Matter changes form and moves from place to place.**
- **Energy changes from one form to another, but it cannot be created or destroyed.**
- **Physical forces affect the movement of all matter on Earth and throughout the universe.**

the BIG idea

Each chapter begins with a big idea. Keep in mind that each big idea relates to one or more of the unifying principles.

UNIFYING PRINCIPLE

Matter is made of particles too small to see.

This simple statement is the basis for explaining an amazing variety of things about the world. For example, it explains why substances can exist as solids, liquids, and gases, and why wood burns but iron does not. Like the tiles that make up this mosaic picture, the particles that make up all substances combine to make patterns and structures that can be seen. Unlike these tiles, the individual particles themselves are far too small to see.

What It Means

To understand this principle better, let's take a closer look at the two key words: *matter* and *particles.*

Matter

Objects you can see and touch are all around you. The materials that these objects are made of are called **matter.** All living things—even you—are also matter. Even though you can't see it, the air around you is matter too. Scientists often say that matter is anything that has mass and takes up space. **Mass** is a measure of the amount of matter in an object. We use the word **volume** to refer to the amount of space an object or a substance takes up.

Particles

The tiny particles that make up all matter are called **atoms.** Just how tiny are atoms? They are far too small to see, even through a powerful microscope. In fact, an atom is more than a million times smaller than the period at the end of this sentence.

There are more than 100 basic kinds of matter called **elements.** For example, iron, gold, and oxygen are three common elements. Each element has its own unique kind of atom. The atoms of any element are all alike but different from the atoms of any other element.

Many familiar materials are made of particles called molecules. In a **molecule,** two or more atoms stick together to form a larger particle. For example, a water molecule is made of two atoms of hydrogen and one atom of oxygen.

Why It's Important

Understanding atoms and molecules makes it possible to explain and predict the behavior of matter. Among other things, this knowledge allows scientists to

- explain why different materials have different characteristics
- predict how a material will change when heated or cooled
- figure out how to combine atoms and molecules to make new and useful materials

UNIFYING PRINCIPLE

Matter changes form and moves from place to place.

You see matter change form every day. You see the ice in your glass of juice disappear without a trace. You see a black metal gate slowly develop a flaky, orange coating. Matter is constantly changing and moving.

What It Means

Remember that matter is made of tiny particles called atoms. Atoms are constantly moving and combining with one another. All changes in matter are the result of atoms moving and combining in different ways.

Matter Changes and Moves

You can look at water to see how matter changes and moves. A block of ice is hard like a rock. Leave the ice out in sunlight, however, and it changes into a puddle of water. That puddle of water can eventually change into water vapor and disappear into the air. The water vapor in the air can become raindrops, which may fall on rocks, causing them to weather and wear away. The water that flows in rivers and streams picks up tiny bits of rock and carries them from one shore to another. Understanding how the world works requires an understanding of how matter changes and moves.

Matter Is Conserved

No matter was lost in any of the changes described above. The ice turned to water because its molecules began to move more quickly as they got warmer. The bits of rock carried away by the flowing river were not gone forever. They simply ended up farther down the river. The puddles of rainwater didn't really disappear; their molecules slowly mixed with molecules in the air.

Under ordinary conditions, when matter changes form, no matter is created or destroyed. The water created by melting ice has the same mass as the ice did. If you could measure the water vapor that mixes with the air, you would find it had the same mass as the water in the puddle did.

Why It's Important

Understanding how mass is conserved when matter changes form has helped scientists to

- describe changes they see in the world
- predict what will happen when two substances are mixed
- explain where matter goes when it seems to disappear

UNIFYING PRINCIPLE

Energy changes from one form to another, but it cannot be created or destroyed.

When you use energy to warm your food or to turn on a flashlight, you may think that you "use up" the energy. Even though the campstove fuel is gone and the flashlight battery no longer functions, the energy they provided has not disappeared. It has been changed into a form you can no longer use. Understanding how energy changes forms is the basis for understanding how heat, light, and motion are produced.

What It Means

Changes that you see around you depend on energy. **Energy,** in fact, means the ability to cause change. The electrical energy from an outlet changes into light and heat in a light bulb. Plants change the light energy from the Sun into chemical energy, which animals use to power their muscles.

Energy Changes Forms

Using energy means changing energy. You probably have seen electric energy changing into light, heat, sound, and mechanical energy in household appliances. Fuels like wood, coal, and oil contain chemical energy that produces heat when burned. Electric power plants make electrical energy from a variety of energy sources, including falling water, nuclear energy, and fossil fuels.

Energy Is Conserved

Energy can be converted into forms that can be used for specific purposes. During the conversion, some of the original energy is converted into unwanted forms. For instance, when a power plant converts the energy of falling water into electrical energy, some of the energy is lost to friction and sound.

Similarly, when electrical energy is used to run an appliance, some of the energy is converted into forms that are not useful. Only a small percentage of the energy used in a light bulb, for instance, produces light; most of the energy becomes heat. Nonetheless, the total amount of energy remains the same through all these conversions.

The fact that energy does not disappear is a law of physical science. The **law of conservation of energy** states that energy cannot be created or destroyed. It can only change form.

Why It's Important

Understanding that energy changes form but does not disappear has helped scientists to

- predict how energy will change form
- manage energy conversions in useful ways
- build and improve machines

UNIFYING PRINCIPLE

Physical forces affect the movement of all matter on Earth and throughout the universe.

What makes the world go around? The answer is simple: forces. Forces allow you to walk across the room, and forces keep the stars together in galaxies. Consider the forces acting on the rafts below. The rushing water is pushing the rafts forward. The force from the people paddling helps to steer the rafts.

What It Means

A **force** is a push or a pull. Every time you push or pull an object, you're applying a force to that object, whether or not the object moves. There are several forces—several pushes and pulls—acting on you right now. All these forces are necessary for you to do the things you do, even sitting and reading.

- You are already familiar with the force of gravity. **Gravity** is the force of attraction between two objects. Right now gravity is at work pulling you to Earth and Earth to you. The Moon stays in orbit around Earth because gravity holds it close.
- A contact force occurs when one object pushes or pulls another object by touching it. If you kick a soccer ball, for instance, you apply a contact force to the ball. You apply a contact force to a shopping cart that you push down a grocery aisle or a sled that you pull up a hill.
- **Friction** is the force that resists motion between two surfaces pressed together. If you've ever tried to walk on an icy sidewalk, you know how important friction can be. If you lightly rub your finger across a smooth page in a book and then across a piece of sandpaper, you can feel how the different surfaces produce different frictional forces. Which is easier to do?
- There are other forces at work in the world too. For example, a compass needle responds to the magnetic force exerted by Earth's magnetic field, and objects made of certain metals are attracted by magnets. In addition to magnetic forces, there are electrical forces operating between particles and between objects. For example, you can demonstrate electrical forces by rubbing an inflated balloon on your hair. The balloon will then stick to your head or to a wall without additional means of support.

Why It's Important

Although some of these forces are more obvious than others, physical forces at work in the world are necessary for you to do the things you do. Understanding forces allows scientists to

- predict how objects will move
- design machines that perform complex tasks
- predict where planets and stars will be in the sky from one night to the next

The Nature of Science

You may think of science as a body of knowledge or a collection of facts. More important, however, science is an active process that involves certain ways of looking at the world.

Scientific Habits of Mind

Scientists are curious. They are always asking questions. Scientists have asked questions such as, "What is the smallest form of matter?" and "How do the smallest particles behave?" These and other important questions are being investigated by scientists around the world.

Scientists are observant. They are always looking closely at the world around them. Scientists once thought the smallest parts of atoms were protons, neutrons, and electrons. Later, protons and neutrons were found to be made of even smaller particles called quarks.

Scientists are creative. They draw on what they know to form possible explanations for a pattern, an event, or an interesting phenomenon that they have observed. Then scientists create a plan for testing their ideas.

Scientists are skeptical. Scientists don't accept an explanation or answer unless it is based on evidence and logical reasoning. They continually question their own conclusions and the conclusions suggested by other scientists. Scientists trust only evidence that is confirmed by other people or methods.

Scientists cannot always make observations with their own eyes. They have developed technology, such as this particle detector, to help them gather information about the smallest particles of matter.

Scientists ask questions about the physical world and seek answers through carefully controlled procedures. Here a researcher works with supercooled magnets.

Science Processes at Work

You can think of science as a continuous cycle of asking and seeking answers to questions about the world. Although there are many processes that scientists use, scientists typically do each of the following:

- Observe and ask a question
- Determine what is known
- Investigate
- Interpret results
- Share results

Observe and Ask a Question

It may surprise you that asking questions is an important skill. A scientific process may start when a scientist asks a question. Perhaps scientists observe an event or a process that they don't understand, or perhaps answering one question leads to another.

Determine What Is Known

When beginning an inquiry, scientists find out what is already known about a question. They study results from other scientific investigations, read journals, and talk with other scientists. A scientist working on subatomic particles is most likely a member of a large team using sophisticated equipment. Before beginning original research, the team analyzes results from previous studies.

Investigate

Investigating is the process of collecting evidence. Two important ways of investigating are observing and experimenting.

Observing is the act of noting and recording an event, a characteristic, or anything else detected with an instrument or with the senses. A researcher may study the properties of a substance by handling it, finding its mass, warming or cooling it, stretching it, and so on. For information about the behavior of subatomic particles, however, a researcher may rely on technology such as scanning tunneling microscopes, which produce images of structures that cannot be seen with the eye.

An **experiment** is an organized procedure to study something under controlled conditions. In order to study the effect of wing shape on the motion of a glider, for instance, a researcher would need to conduct controlled studies in which gliders made of the same materials and with the same masses differed only in the shape of their wings.

Scanning tunneling microscopes create images that allow scientists to observe molecular structure.

Physical chemists have found a way to observe chemical reactions at the atomic level. Using lasers, they can watch bonds breaking and new bonds forming.

Forming hypotheses and making predictions are two of the skills involved in scientific investigations. A **hypothesis** is a tentative explanation for an observation, a phenomenon, or a scientific problem that can be tested by further investigation. For example, in the mid-1800s astronomers noticed that the planet Uranus departed slightly from its expected orbit. One astronomer hypothesized that the irregularities in the planet's orbit were due to the gravitational effect of another planet—one that had not yet been detected. A **prediction** is an expectation of what will be observed or what will happen. A prediction can be used to test a hypothesis. The astronomers predicted that they would discover a new planet in the position calculated, and their prediction was confirmed with the discovery of the planet Neptune.

Interpret Results

As scientists investigate, they analyze their evidence, or data, and begin to draw conclusions. **Analyzing data** involves looking at the evidence gathered through observations or experiments and trying to identify any patterns that might exist in the data. Scientists often need to make additional observations or perform more experiments before they are sure of their conclusions. Many times scientists make new predictions or revise their hypotheses.

Often scientists use computers to help them analyze data. Computers reveal patterns that might otherwise be missed.

Scientists use computers to create models of objects or processes they are studying. This model shows carbon atoms forming a sphere.

Share Results

An important part of scientific investigation is sharing results of experiments. Scientists read and publish in journals and attend conferences to communicate with other scientists around the world. Sharing data and procedures gives them a way to test one another's results. They also share results with the public through newspapers, television, and other media.

The Nature of Technology

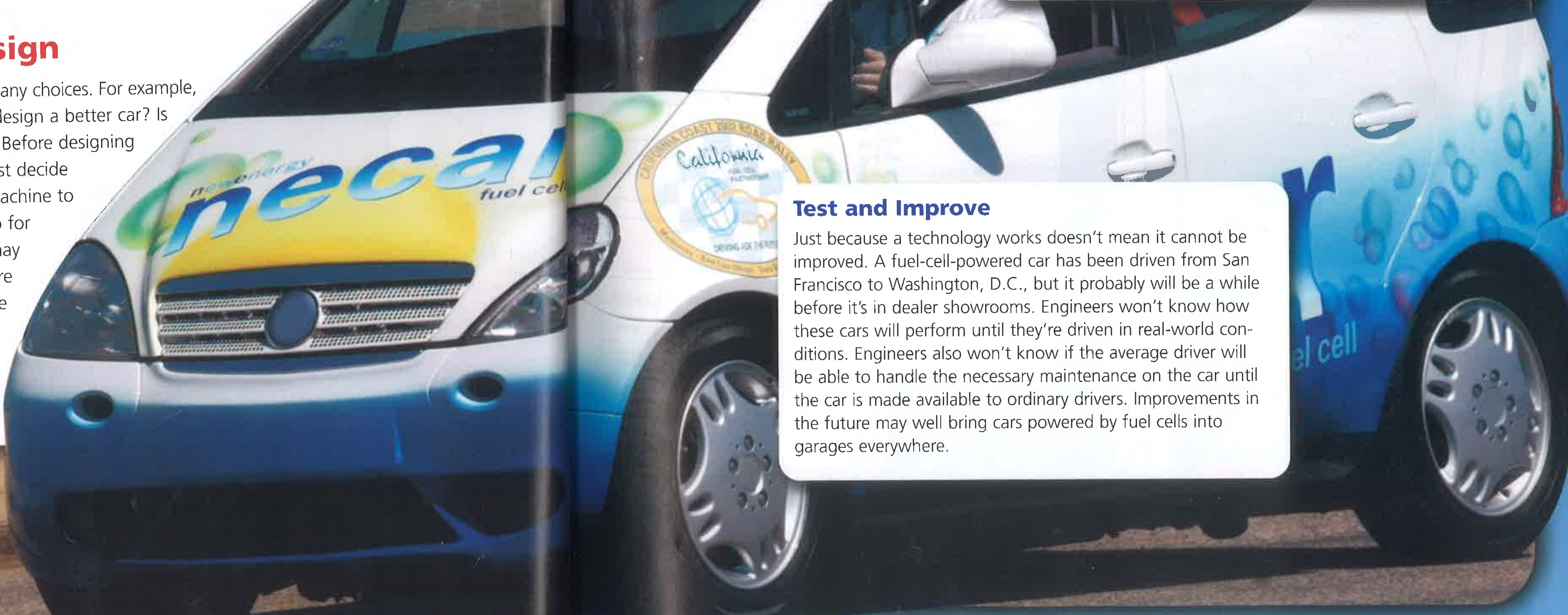
When you think of technology, you may think of cars, computers, and cell phones, as well as refrigerators, radios, and bicycles. Technology is not only the machines and devices that make modern lives easier, however. It is also a process in which new methods and devices are created. Technology makes use of scientific knowledge to design solutions to real-world problems.

Science and Technology

Science and technology go hand in hand. Each depends upon the other. Even designing a device as simple as a toaster requires knowledge of how heat flows and which materials are the best conductors of heat. Just as technology based on scientific knowledge makes our lives easier, some technology is used to advance scientific inquiry itself. For example, researchers use a number of specialized instruments to help them collect data. Microscopes, telescopes, spectrographs, and computers are just a few of the tools that help scientists learn more about the world. The more information these tools provide, the more devices can be developed to aid scientific research and to improve modern lives.

The Process of Technological Design

The process of technology involves many choices. For example, how does an automobile engineer design a better car? Is a better car faster? safer? cheaper? Before designing any new machine, the engineer must decide exactly what he or she wants the machine to do as well as what may be given up for the machine to do it. A faster car may get people to their destinations more quickly, but it may cost more and be less safe. As you study the technological process, think about all the choices that were made to build the technologies you use.



Identify a Need

Successful technology fills a need; it helps us perform a task we need or want to do. For example, as more cars appear on the road, noise and air pollution become serious threats to the environment and to people's health. Gas consumption also depletes precious petroleum resources. There is a need to find a fuel source for a car that will not pollute the air and that will never run out.

Design and Develop

Hydrogen fuel cells are a potential solution to this need. These cells combine hydrogen and oxygen into water, producing electricity in the process. Engineers have found a way to make fuel cells small enough to fit into a car, yet able to produce enough electricity to power an electric motor. Before arriving at this final design, engineers tried many others.

Test and Improve

Just because a technology works doesn't mean it cannot be improved. A fuel-cell-powered car has been driven from San Francisco to Washington, D.C., but it probably will be a while before it's in dealer showrooms. Engineers won't know how these cars will perform until they're driven in real-world conditions. Engineers also won't know if the average driver will be able to handle the necessary maintenance on the car until the car is made available to ordinary drivers. Improvements in the future may well bring cars powered by fuel cells into garages everywhere.

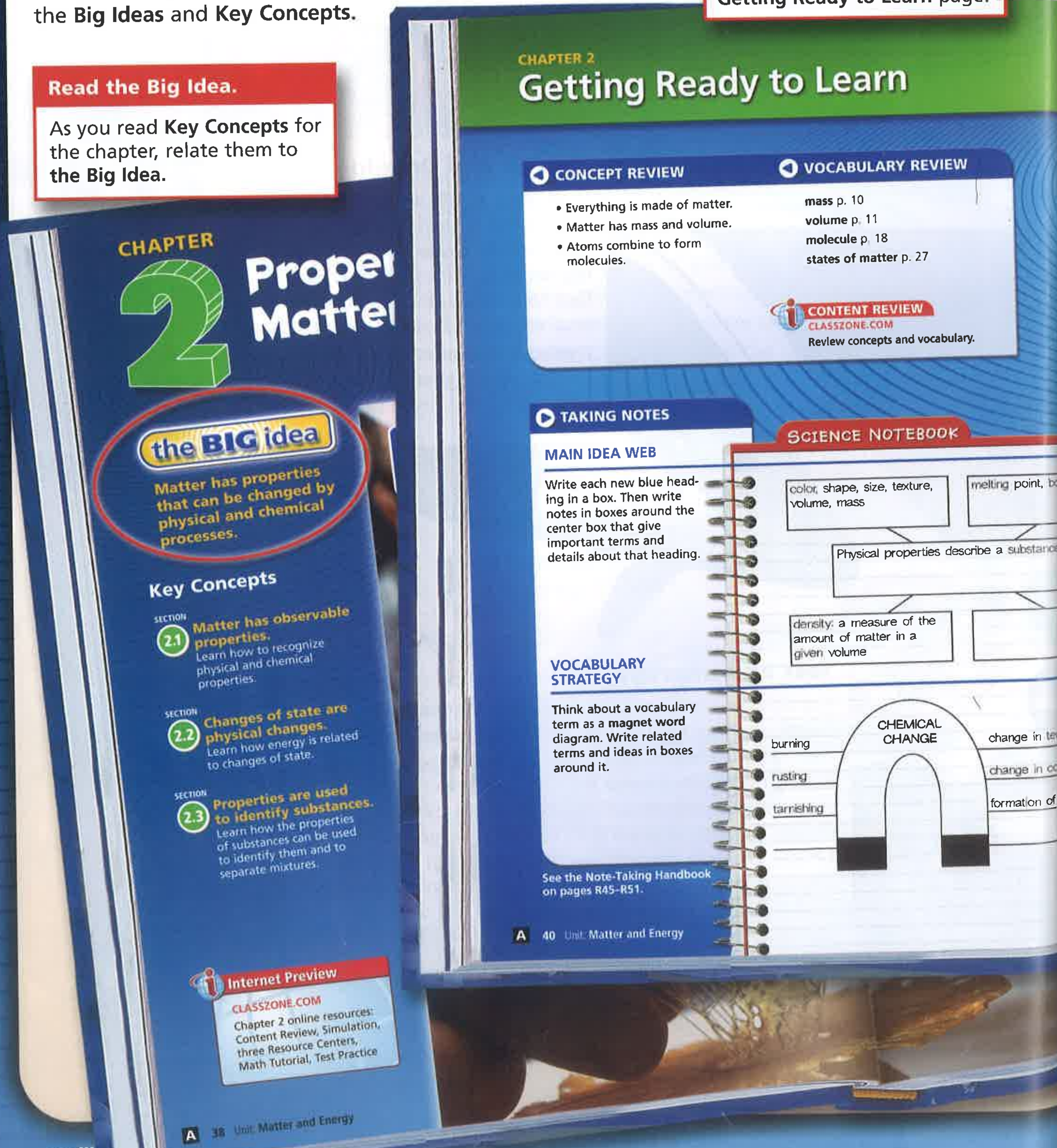
Using McDougal Littell Science

Reading Text and Visuals

This book is organized to help you learn. Use these boxed pointers as a path to help you learn and remember the **Big Ideas** and **Key Concepts**.

Read the Big Idea.
As you read **Key Concepts** for the chapter, relate them to **the Big Idea.**

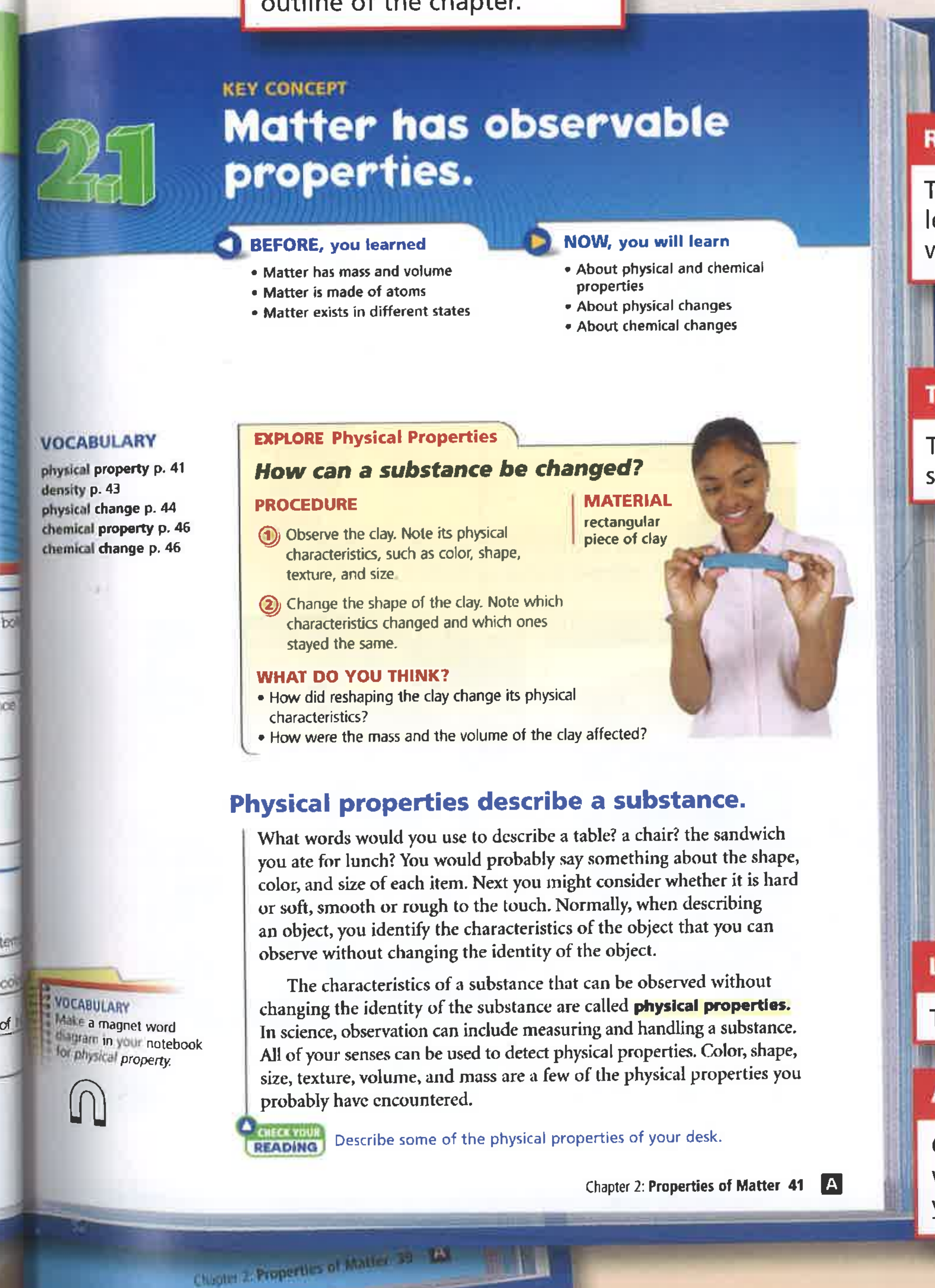
Take notes.
Use the strategies on the **Getting Ready to Learn** page.



Read each heading.
See how it fits into the outline of the chapter.

Remember what you know.
Think about concepts you learned earlier and preview what you'll learn now.

Try the activities.
They will introduce you to science concepts.



Learn the vocabulary.
Take notes on each term.

Answer the questions.
Check Your Reading questions will help you remember what you read.

Reading Text and Visuals

Read one paragraph at a time.

Look for a topic sentence that explains the main idea of the paragraph. Figure out how the details relate to that idea. One paragraph might have several important ideas; you may have to reread to understand.

Answer the questions.

Check Your Reading questions will help you remember what you read.

Study the visuals.

- Read the title.
- Read all labels and captions.
- Figure out what the picture is showing. Notice colors, arrows, and lines.
- Answer the question. **Reading Visuals** questions will help you understand the picture.

Physical Properties

How do you know which characteristics are physical properties? Just ask yourself whether observing the property involves changing the substance to a different substance. For example, you can stretch a rubber band. Does stretching the rubber band change what it is made of? No. The rubber band is still a rubber band before and after it is stretched. It may look a little different, but it is still a rubber band.

Mass and volume are two physical properties. Measuring these properties does not change the identity of a substance. For example, a lump of clay might have a mass of 200 grams (g) and a volume of 100 cubic centimeters (cm^3). If you were to break the clay in half, you would have two 100 g pieces of clay, each with a volume of 50 cm^3. You can bend and shape the clay too. Even if you were to mold a realistic model of a car out of the clay, it still would be a piece of clay. Although you have changed some of the properties of the object, such as its shape and volume, you have not changed the fact that the substance you are observing is clay.

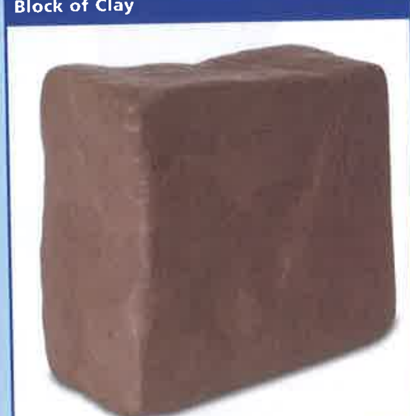
REMINDER: Because all formulas for volume involve the multiplication of three measurements, volume has a unit that is cubed (such as cm^3).

CHECK YOUR READING: Which physical properties listed above are found by taking measurements? Which are not?

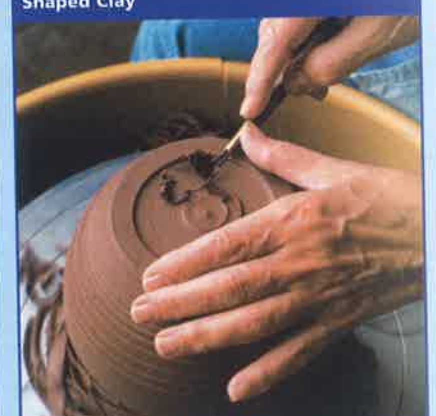
Physical Properties

Physical properties of clay—such as volume, mass, color, texture, and shape—can be observed without changing the fact that the substance is clay.

Block of Clay



Shaped Clay



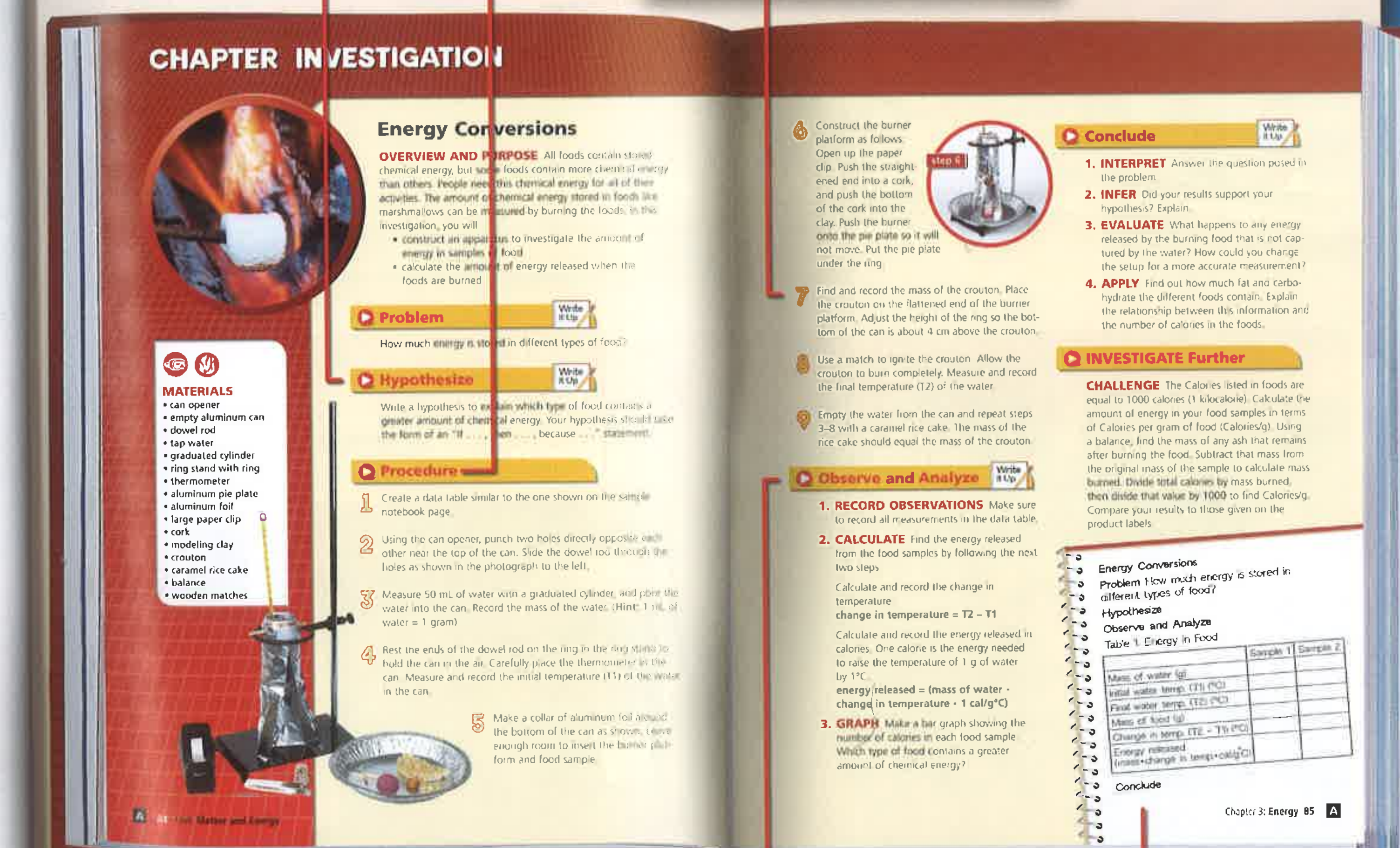
READING VISUALS: COMPARE AND CONTRAST Which physical properties do the two pieces of clay have in common? Which are different?

42 Unit: Matter and Energy

Doing Labs

To understand science, you have to see it in action. Doing labs helps you understand how things really work.

1. Read the entire lab first.
2. Form a hypothesis.
3. Follow the procedure.
4. Record the data.



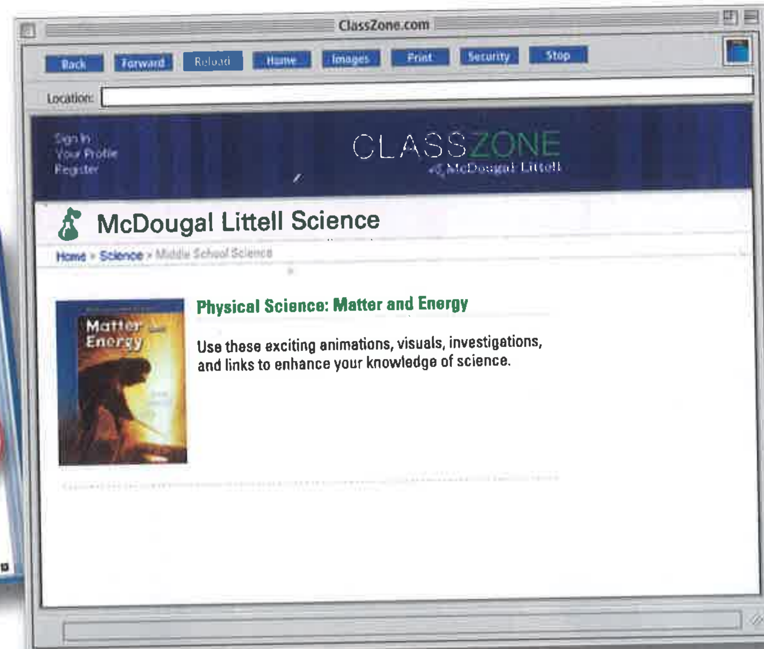
5. Analyze your results.
6. Write your lab report.

Using Technology

The Internet is a great source of information about up-to-date science. The ClassZone Web site and SciLinks have exciting sites for you to explore. Video clips and simulations can make science come alive.

Look for red banners.

Go to **classzone.com** to see simulations, visualizations, and content review.



Watch the videos.

See science at work in the **Scientific American Frontiers video.**

Look up SciLinks.

Go to **scilinks.org** to explore the topic.

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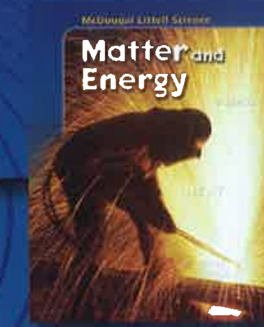


Matter and Energy Contents Overview

Unit Features

FRONTIERS in Science

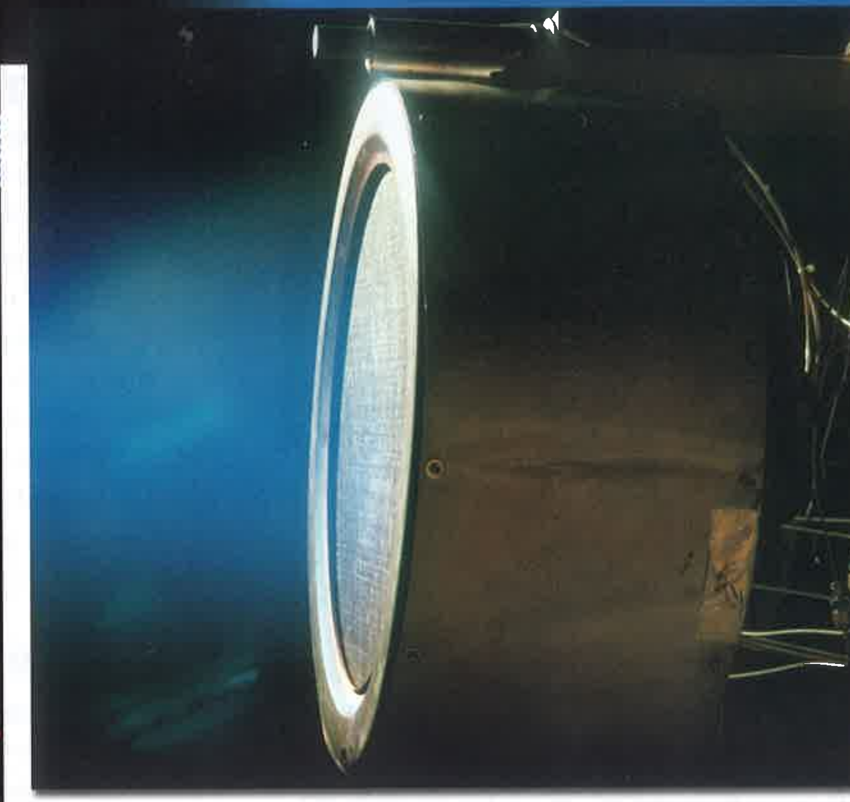
FUELS of the FUTURE

Where does this spacecraft get its fuel?

Deep Space 1 was an experimental design. Its successful mission prepared the way to the development of more ion-propelled spacecraft.

SCIENTIFIC AMERICAN FRONTIERS

View the "Sunrayce" segment of your *Scientific American Frontiers* video to learn about a cross-country race in which cars use solar power instead of gasoline.



The stream of ions glows blue as it is shot out of an ion-propulsion engine.

Ion Engines for Long Voyages

Rocket engines must provide huge amounts of energy to move spacecraft away from Earth and keep them in orbit. The fuel required can weigh more than the spacecraft themselves. That is why scientists and engineers are always looking for more efficient ways to give spacecraft and other vehicles the energy to move.

One method of powering spacecraft uses electrically charged particles called ions. The atoms of a gas—usually xenon—are first made into ions. An electric field is then used to pull these ions out of the engine at a very high speed—faster than 100,000 kilometers per hour (62,000 mi/h). This stream of rapidly moving ions works like the gases coming out of a jet engine on a plane—propelling the spacecraft in the direction opposite to the ion stream.

An advantage of ion propulsion is that its fuel is much lighter than the chemical fuel used in rockets. Ion propulsion does not provide enough thrust to be used for a rocket launch, but it can be used to move a spacecraft through long distances in outer space. This method of propulsion provides a small force to the spacecraft; however, over time the spacecraft can reach great speeds.

The space probe *Deep Space 1* was the first to use an ion engine to travel between planets. The engine generated enough speed for the probe to follow and photograph comet Borrelly in 2001.

Solar sails will reflect sunlight to move a spacecraft through space.

Running on Sunlight

Solar energy is used for travel in outer space, where there is plenty of sunlight and very little friction to slow down a spacecraft. However, once a spacecraft travels far away from the Sun—as far as the outer planets Jupiter and Saturn—the amount of energy reaching it is far less than the energy it was getting near Earth. The sunlight can be helpful only if solar cells on the vehicle can collect enough of it. One solution is to reflect sunlight. Scientists are developing solar sails, which will act like enormous mirrors. The pressure of reflected sunlight on the sails can be used to move a large ship through space—even far from the Sun.

Beaming Energy from Earth

Another way to power a spacecraft is to send energy to it all the way from Earth. This idea is called beamed energy propulsion. A beam delivers energy to solar sails on the spacecraft. The energy can be in the form of microwaves—the same energy that heats food in a microwave oven or delivers calls on a cell phone. Or it can be in the form of laser light, a very concentrated beam of visible light. This method has already been used successfully to power very small vehicles, 10 centimeters (4 in.) long. Experiments are under way with larger spacecraft.

Combined Technologies

Some recent space flights have combined common and experimental technologies. For example, the *Cassini* space probe has two regular rocket engines for propulsion. Other energy comes from three generators powered by radioactive decay. This combination of engines allowed *Cassini* to be the largest and most complicated spacecraft ever launched. Its goal is to explore Saturn.

SCIENTIFIC AMERICAN FRONTIERS

View the "Sunrayce" segment of your *Scientific American Frontiers* video to see what is involved in solar-car racing.

IN THIS SCENE FROM THE VIDEO Students from California State University, Los Angeles, work on their solar car.

CATCHING THE SUN'S RAYS Since 1990 teams of college students have built and raced solar-powered cars. The races are held every two years to promote awareness of solar energy and to inspire young people to work in science and engineering.

Solar cells on the cars' bodies convert sunlight into electricity. The goal is to make lightweight cars that convert sunlight efficiently. Today's solar cars can reach speeds of up to 75 miles per hour, but the average racing speed is 25 miles per hour. On cloudy or rainy days, the teams conserve power by traveling more slowly—or risk running down their batteries.

In 2003 the American Solar Challenge took place on historic Route 66 from Chicago to Claremont, California. At 3700 kilometers (2300 mi), the ten-day event was the longest solar-car race in the world.

Alternative Fuels on Earth

Scientists and inventors have long been looking for practical alternative fuels to power vehicles on Earth as well as in outer space. Most vehicle engines on Earth use gasoline or other fossil fuels. These fuels are based on resources, such as petroleum, that are found in underground deposits. Those deposits will not be replaced for millions of years. Solar energy, by contrast, is endlessly renewable, so it seems to be a good alternative to nonrenewable fossil fuels.

Solar-powered cars rely on solar cells, which convert the energy of sunlight directly into electrical energy that can be stored in batteries. One outstanding solar car was built by Dutch students and entered in the 2001 World Solar Challenge.

The students' car, called the *Nuna,* used several technologies that had been developed for space travel. Its body was reinforced with Kevlar, a space-age material that is also used in satellites, space suits, and bulletproof vests. During the race, the *Nuna* covered 3010 kilometers of desert in Australia, breaking solar-car speed records, and won the race.

Does the development of solar cars like the *Nuna* mean that most people will be driving solar cars soon? Unfortunately, such cars run only when the Sun is shining unless they rely on batteries—and it takes hundreds of pounds of batteries to store the amount of energy in a gallon of gasoline. As with spacecraft, the goal is to design a vehicle in which the fuel doesn't outweigh the vehicle itself.

UNANSWERED Questions

Even as scientists and inventors solve problems in solar technology, new questions arise.

- Can solar technology be made affordable?
- Is solar technology practical for large-scale public transportation?
- Are there any hidden costs to the use of alternative fuels?

UNIT PROJECTS

As you study this unit, work alone or with a group on one of these projects.

Build a Solar Oven

Design and build a solar oven that can boil a quarter cup of water.

- Plan and sketch a design for a solar oven that can reach 100°C.
- Collect materials and assemble your oven. Then conduct trials and improve your design.

Multimedia Presentation

Create an informative program on solar race cars and the way they work.

- Collect information about solar race cars. Research how they are powered.
- Examine why solar cars have specific shapes. Learn how the solar panels and batteries work together.
- Give a multimedia presentation describing what you learned.

Design an Experiment

Design an experiment that compares how well two of the following alternative energy sources move an object: solar energy, wind power, biomass (fuel from plant material), waste-material fuel, hydrogen fuel cells, heat exchangers.

- Research the energy sources, and pick two types to compare.
- List materials for your experiment. Create a data table and write up your procedure.
- Describe your experiment for the class.

CAREER CENTER
CLASSZONE.COM

Learn more about careers in electrical engineering.